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LAMINATED INTERGLACIAL CLAYS OF GRANTSBURG, WIS.

[WITH CHRONOLOGICAL DEDUCTIONS.]

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GRANTSBURG, Wis., is in Burnett county. The St. Croix River forms the western boundary of the county, separating it from Minnesota. Two large streams enter the St. Croix from the east; one, known as Clam River, crosses the central portion of the county, and the other, Wood River, crosses well toward the south. Both, in their lower courses, cut entirely through the capping drift deep into a stratified clay deposit that forms the subject of this paper.

At all points the clays lie beneath a later and coarser sheet of either modified drift or till, or both. This capping varies in thickness from a few feet to possibly 50 feet, or even more. Yet the general surface of the country is extremely level over large tracts. Swamps and so-called meadows of immense size are a common feature. But the remainder of the district known to be underlain by the clay bed is typical sand barrens. That the clays extend also beneath the adjoining morainic belt forming the southeastern margin of the sand tract is indicated by characters in the deposits themselves, although their actual presence in that direction is not a matter of observation.

Extent.—One margin of the deposit is near the mouth of Wood River. The thickness there at its best exposure is only 5 feet. The broad St. Croix valley then cuts into this margin, and beyond no trace of the clays has yet been found. Exposures on Clam River lie 15–18 miles northeastward from those to be seen on the Wood. A total thickness there of over 40 feet seems to indicate that the margin in that direction is still some distance away. The same is true of the eastward extent, as noted above, while toward the west the broad St. Croix valley has destroyed the southern portion, at least on that side. There is, however, at one point on the west side of the St.

Croix, on Snake River about 6 miles above its mouth, a deposit of laminated clays that might be interpreted as a marginal facies, but with no intervening exposures there is doubt about this connection.

Although exact boundaries, therefore, are not known, an extent of at least 20 miles north and south, and a width of 10-15 miles, are certain. Thus the area known to be underlain by these clays is about 250 square miles. The probable area is still greater, but in some directions the margins are hopelessly buried beneath heavier glacial deposits.

Thickness.—At Grantsburg 15 feet of the stratified clays are exposed in the workings of the Terra Cotta Brick Co. Mr. Ira C. Jones, the manager, at the writer's suggestion, bored entirely through the deposit, and reports a total of 35 feet at that point. There is, however, at the same place clear evidence of the removal of some of the topmost material by later ice-advance. How much should be accounted for in this way no one can tell, but the original thickness was certainly more than 35, and probably less than 40, feet.

Near the mouth of Wood River, as noted above, the same deposit is 5 feet thick.

On Clam River, with 40 feet exposed, the deposit is not entirely cut through. An undulating habit of the lowermost laminae, however, seems to indicate proximity to the floor.

Character.—These clays are all strongly laminated. The laminae vary in thickness from a mere film to several inches in different parts of the deposit, but are comparatively uniform in any particular zone. Their average thickness in the upper part of the deposit is about a quarter of an inch. The average thickness nearer the middle is about one-tenth of an inch. Less uniformity is observable near the top than in any other zone.

The lamination is extremely regular and approximately horizontal. Small crumplings or bunchings occur, but are rare.

The general color is red from top to bottom. On closer inspection, however, the laminae are seen to be of two types—a deep red one, and a gray, which alternate without exception throughout the deposit.

Very perfect water-sorting is evident from a study of these individual laminae. The gray ones are comparatively coarse-grained, containing maximum diameter of 0.06^{mm} . Diameters of 0.02 to

0.03^{mm} are very common, while of course there is much finer matter. The red laminae are composed of extremely fine grains and flakes. There are no grains at all comparable to the sizes given above. Average diameters are less than 0.002^{mm}.

The passage from one type to the other is sometimes gradual and sometimes abrupt. As a rule, the gradual changes hold for all cases in passing upward from a gray to a red lamina. The abrupt changes are noted in passage upward from a red to a gray one. Evidently there is some sort of unity between each gray lamina and the overlying red one throughout the series.

Taking, therefore, the double lamina—*i. e.*, a gray and the succeeding red one above—as a unit, the following facts obtain: The most irregular lines in the lamination are at the very base of the gray laminae. There are sinuosities on a small scale that simulate erosion unconformities. The coarsest grains seen anywhere in the material are in these small embayments along this line. There is an occasional streakiness of the gray laminae with the finer red material, but not uniformly developed. The change to red, in rising from the base of the gray lamina, takes place very gradually and gives a much more even line or band than that at the base. The change to red color is no more marked than the change to finer and finer grain. There is no streakiness in the red layers.

At Clam River there is some modification of these characters. The proportion of gray material is greater. The upper 20 feet of that deposit are decidedly gray and sandy. Lower down, however, the red layers assume their accustomed character, relations, and importance, and are of even more than the usual thickness.

Composition.—Much of the clay matter is so extremely fine that identification in the grain is of doubtful accuracy. Among the coarser fragments quartz is most abundant. Feldspar, garnet, tourmaline, mica, and kaolin are also recognized. As a whole, the gray laminae are extremely siliceous, while the red are by strong contrast argillaceous.

“Clay dogs,” small limy concretions, occur in the upper part of the deposit at Grantsburg.

Chemical analysis shows a higher percentage of lime and magnesia than would be expected from the color of the material. Iron,

however, is prominent enough to overcome their effects, so that the burned wares are all red.

Where successive laminæ are so divergent in characters, it is evident that there might be considerable difference in chemical analysis from different samples. For ordinary brick-making purposes the material is mixed as thoroughly as possible with the equipment of the plant. Such a mixture would best represent the composition of the deposit as a whole. Nearly all the work yet done has been upon the upper zone of about 15 feet. Two samples out of this zone give the following results in a partial analysis. No. I is mixed material and fairly representative. No. II is from the uppermost layers.

	I	II
Silica, SiO_2	58.52%	64.76%
Alumina, Al_2O_3	14.98	15.45
Iron, Fe_2O_3	7.92	4.86
Lime, CaO	5.26	4.22
Magnesia, MgO	3.39	4.02
Water, H_2O	7.92	5.96
	97.96	99.17

This leaves a balance of 2.04 and 0.83 per cent., respectively, for the undetermined constituents.

Economic value.—With moderately thorough mixing the Grantsburg laminated clays make common stiff mud brick of excellent quality. The fineness of grain and plasticity aid in producing an unusually smooth finish. With hard burning the product is remarkably strong. The colors are all classed as red, but exhibit considerable range of shades, the hardest-burned lots being darkest in color. Likewise the more exposed margins have darker color, so that systematic setting of the kiln with this result in view produces a variegated ware that is considered attractive.

All wares require a temperature of about 2,000° F. in burning. The upper beds of Clam River are too sandy for use as clays at all. At all other points, however, with careful mixing the material is valuable for clay wares. Vitrified bricks have been made by the company now operating at Grantsburg which seem to duplicate the

most approved paving quality. Ornamental terra-cotta, however, is the most promising line of development to which this clay lends itself.

In practice the chief problem is to secure complete intermixture of the two types of laminæ. They have very different shrinkage and fusibility. When the mixing is thorough, however, the result is a clay of superior quality and capable of use in higher grades of wares.

Geological relationships.—Evidence as to the age and origin of this deposit has been in part involved in the preceding description. The laminated clays rest upon a thick accumulation of red glacial till of typical late Wisconsin character. At the mouth of Wood River this is well exposed. Occasional horizontal markings seen here throughout a thickness of about 40 feet of this till are thought to indicate standing water during its deposition. On the St. Croix, half a mile away, this same till in turn rests upon the eroded surface of white and yellow friable Cambrian sandstone.

Everywhere above the clays rests a sand or till capping, or a mixture of both. It contains coarse sand in greatest quantity, but also gravel and boulders. At the clay pits near Grantsburg, the overlying gravelly till also contains an occasional pyritiferous and carbonaceous nodule very like those sometimes seen in lignite horizons. There are also numerous chunks, angular fragments, of laminated clay, of the size of small boulders which, in connection with the furrowed or uneven surface of the clay deposit itself, argues a plowing up of some of this material by subsequent advance of glacial ice. The capping drift does not show water marking, and is of variable thickness, with occasional typical morainic aspect. Wherever the surface is level for any considerable area the sloughs and meadows are found. These are a surprising phenomenon in a country that appears to be all sand, but no doubt the effective bottom is formed by the underlying laminated clay beds.

It is clear that the clay deposit was accumulated some time in the late Wisconsin stage of the Glacial period. Heavy deposits of Wisconsin till preceded the clays, and there was a readvance of the ice covering the whole area again after the laminated clays were laid down. The thin cap left by this last advance, and the little disturbance of previous deposits, argue a place at the immediate close of the stage for this locality.

The larger development of sands immediately upon and after the deposition of fine clays of so great extent seems to indicate a long-continued assorting of materials, carrying the fine matter forward and leaving the coarser behind, until a final movement of the chief agency brought them both together a second time—but this time in separate beds. The prevailing sandiness of the upper portion of the laminated deposit at Clam River leads one to regard that direction—*i. e.*, the north or northeast—as nearest to the general supply. This is the region also that constitutes the typical sand barrens of northern Wisconsin. The long, assorting process must have been as prominent a genetic factor with them as the type of bed-rock from which they were obtained.

The laminated clays.—The laminated clays are no doubt a lake deposit. The uniform succession of laminae, the relationship between the red and gray, and the constancy of their characters lead one to look for some uniformly periodic cause of formation.

The presence of comparatively large grains throughout the gray laminae shows a continuance of supply of new material during its accumulation at least, while the presence of some streakiness of finer red matter occasionally in them indicates fluctuations or lulls within this period of supply.

The absence of all large fragments in the red laminae, their uniformity of succession, and their gradual increase in fineness of grain seem to argue a period of complete cessation of supply from without and complete protection from disturbances.

This periodic supply, then, must mark either successive storms or successive thawings of neighboring glacial ice. If the latter, then the period is seasonal, and each unit of lamination, a gray and a succeeding red layer together, represents a year of time. On this supposition, the summer thawings of the glaciers furnished silt to the lake then covering the Grantsburg area, and left behind great quantities of coarser materials to be later spread as the poorest of northern soils. Winters checked the supply, coated the lake with ice, and in this quiet season the finest sediment settled down in the uniform red laminae of the clay deposit.

The deposits themselves have further evidence on this point. It is scarcely conceivable that a supply controlled by spasmodic periods,

such as storms, could produce uniformity either in thickness or in distribution. Variations would be expected to be notable and frequent, and at random with occasional breaks of a much more pronounced character. On the contrary, at any given horizon the thicknesses are comparatively uniform and there are no breaks of a higher order than those of the single unit. If, furthermore, the succeeding laminae represent seasonal supply from a more or less proximate ice margin, succeeding seasons might be expected to give fairly equivalent results, greatest uniformity being developed when the ice margin is distant, and greatest variation when the ice is nearest. Other things being equal, when the supply is near by, a greater quantity of matter would reach the lake in a given season, and in connection with the general tendency or character of the season there ought to be more irregularity and greater thickness of deposit. In terms of the clays themselves, the laminae of the middle zone should be most uniform and of least average thickness, while those of the top and bottom zones should be most variable. This is easily seen to be true in the deposit. The greatest irregularities are near the top. With a retreat of the ice margin to near its maximum withdrawal the middle zone of laminae must have been laid down. A seasonal interpretation accords well with the facts. Even the streakiness seen in the thicker gray layers makes room for storms or other fluctuations within the season itself, and supports the other interpretation for the more uniform breaks.

If the seasonal interpretation may be regarded as established, it remains only to compute the number of units of deposition in order to estimate the number of years the deposit was in accumulating. This done, we need but to connect this episode in the general ice-retreat with its proper limitations in order to get the force of its bearing upon postglacial history.

Time estimates.—For computation a gray and red lamina together make a unit and represent one year. At Grantsburg the deposit is now 35 feet thick, and was originally greater. There are an average of four units to the inch, or forty-eight to the foot, in such portions of the bed as can be critically examined at that point. There are then approximately 1,680 units in the total thickness. It seems fair to conclude from the above computation that the interglacial lake,

producing the laminated clays at Grantsburg, existed 1,700 years, and that the accompanying minor retreat and readvance of the ice-margin consumed the same length of time.

The whole problem of time relation to geologic process is a difficult one. There is no very satisfactory formula for the solution of either a process or an interval in so exact terms as years. The most successful attempts at such solution are for the interval between the final withdrawal of the ice from particular localities and the present time. For the vicinity of Buffalo by means of Niagara Falls, and for the vicinity of Minneapolis by means of St. Anthony Falls, careful estimates have been made and are widely known. In both cases, however, there are variable factors capable of modifying any particular result seriously, and even multiplying the lower estimates many times. The lowest estimates are in general those either published earliest or those which pay the least regard to possible variation of the factors. But there is so far no more precise estimate as to this interval, or any part of it, from any other source.

It is believed, however, that the Grantsburg clay beds furnish just such data, and that, so far as they go, they are more precise than the two familiar examples cited above.

The interval covered by this estimate of 1,700 years measures only one of the minor oscillations of the Lake Superior ice-lobe. In its whole retreat from St. Anthony Falls to the highlands of its source there were doubtless several similar fluctuations. Evidence of this in part is the great development of terminal moraines piled across the region, and the occurrence of similar laminated clay beds at other localities. It would seem as though the time actually required for the retreat of the ice from St. Anthony Falls to Lake Superior alone must have been at least as great as the smallest estimates formerly made for the whole postglacial interval.

Summary.—A laminated clay bed 35 feet thick is exposed on Wood and Clam Rivers in Burnett county, Wisconsin.

The area estimated to be underlain by this deposit is more than 300 square miles in extent.

Excellent bricks are being made, and the material is capable of more uses.

The deposit is of lake origin fed by melting glacial ice.

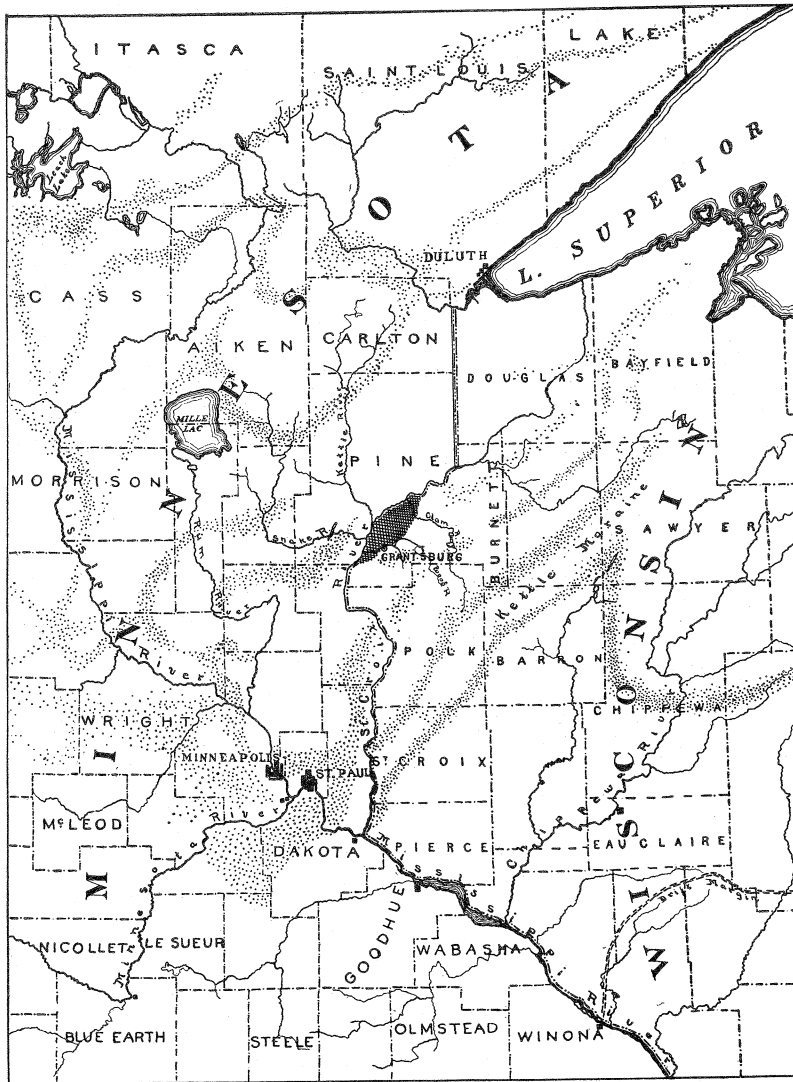


FIG. 1.—Region about the head of Lake Superior, showing location of the Grantsburg clay deposit, and its general relation to the major terminal moraines of the vicinity. (Compiled from the maps of the Minnesota and Wisconsin State Surveys.)

Its age is late Wisconsin stage of the glacial period, and is in a minor way interglacial.

The character of lamination is considered to indicate a seasonal accumulation. Each unit of lamination, therefore, measures a year.

The total thickness of the deposit divided by the average thickness of the unit of lamination gives a number equivalent to the length of time occupied in its accumulation. This is approximately 1,700 years.

If correct at all, the above furnishes a more precise measure for a part of the postglacial interval than is obtained from any other source. The part of this interval involved is but one of the minor fluctuations of the retreating ice in the vicinity of Grantsburg, Wisconsin.

Evidence from this source is opposed to the lowest estimates of postglacial time as computed from Niagara and St. Anthony Falls.